Chameleon windows

Haven't shown their true colors yet

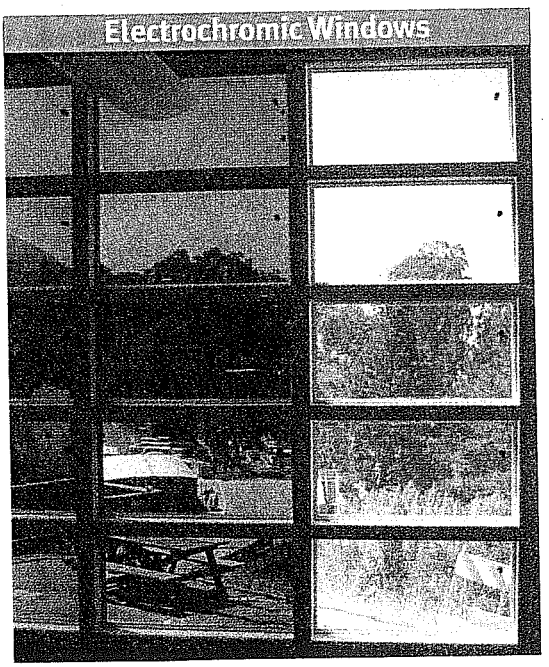
By Bill Kirtz

Everyone loves the potential of electrically switchable "smart glass," but some question whether it can be produced cheaply enough for large-scale commercial use.

A window system that changes its transmission when exposed to sunlight can certainly save consumers billions on peak energy costs. The key will be to produce an affordable, reliable and durable product, and the stakes are high.

Fifteen years ago, the average American home had 12 windows, according to the National Association of Home Builders of Washington, DC. Now, the average home has 16 windows and upscale houses of 4,000 to 5,000 square feet have at least 20.

As rival systems battle for funding and industry support for this growing market, micro-thin, low-emissivity coatings remain the energy-efficient choice for the estimated 20 billion square feet of flat glass produced worldwide each year. They reflect heat, sending it back where it came from, and they boost the thermal quality of insulating glass units, helping homes to stay warmer in winter and cooler in summer.



More than 40 percent of newly installed windows are estimated to have low-emissivity coatings, and low-e products are expected to dominate the market in the future.

Glass designs today can give great solar heat-gain numbers or high light-transmission numbers. What isn't available is a dynamic glass that provides high light transmission on cloudy days and low light transmission on sunny days, while controlling solar heat gain and providing a view. Besides the view, switchable glass has the advantage of using daylight and cutting peak demand, thus saving energy and improving solar heat control.

A 2003 study by Lawrence Berkeley National Laboratory staff scientists in Berkeley, CA, concluded that during the last 15 years, low-e and other technological improvements significantly improved American windows' energy efficiency. But, the study adds, interest in zero-energy homes dictates a new generation of window products. Windows with dynamic solar heat-gain properties offer significant potential in northern and central climates, the study says, while windows with very low-static heat gain offer the most potential in southern climates.

In closely watched trials, SageGlass electrochromic glazing tests continue in a Houston home, a Long Island skylight and in model offices in Oakland, CA. The goal: to demonstrate durability and efficiency so Sage, of Faribault, MN, can work with glass and window manufacturers to create a product for widespread, and particularly commercial use. The data isn't in yet.

Sage's "switchable" windows darken or lighten with a push of a button and control the flow of visible light and solar heat in homes, offices, auto-

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mobiles and other places. Consumers can block all light or just some by turning a knob, creating huge savings on heating, cooling and lighting costs.

Currently, electrochromic glass is used in small-scale applications, such as rearview mirrors. Mike Myser, Sage vice president for sales and marketing, says the technology would pay for itself within two to three years if used in large applications.

The company has won several Small Business Innovation Research awards through the U.S. Department of Commerce, the Department of Energy, the National Science Foundation and the Department of Defense. It has passed several DOE tests, and is the first to receive DOE approval for durability.

The full-scale window tests feature windows manufactured by Pilkington North America of Toledo, with two identical side-by-side offices: one with manual controls and the other with automatic controls. Eleanor Lee, manager of the project at the Lawrence Berkeley National Laboratory, noted that the DOE and the California Energy Commission co-sponsored the three-year test to "accelerate" the U.S. market for electrochromatics use.

She says the trials are so far very preliminary, and estimates that it will be five to 10 years before electrochromic technology will be in wide use. Nevertheless, Lee predicts "significant energy savings" in residential and commercial use. "Last summer, we measured significant light energy savings [that] varied day to day depending on weather. We have proved that the concept can work."

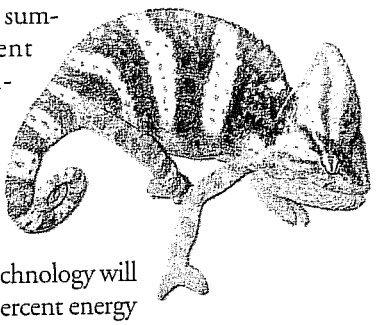
Tests so far show that people prefer automatic controls to static windows, Lee says. "They like windows to switch by themselves. You'd think it would be a bit of 'Big Brother' [controlling people's every movement], but that's not been the case."

Expense is still a factor. Sage windows will have a premium cost when first introduced to the marketplace, driven primarily by volume and production related issues. But the company asserts that as product demand grows and production volumes increase, the price of the windows will be about the same as today's higher end windows with shading systems.

Electrochromically Speaking

SageGlass electrochromic glazing consists of five thin-film ceramic layers coated directly onto glass. The solid-state design is formed in much the same manner as low-emissivity glazing. Sage officials claim that EC glazing provides the energy saving and comfort benefits of low-emissivity glass while delivering the special features of intelligent, variable sunlight and heat control, such as variable tint control. They say widespread marketplace adoption of efficient switchable glazing requires this combination.

High-performance low-e glass is 41 percent more energy efficient in summer and 35 percent more energy efficient in winter than standard dual-pane glazing, Sage officials say. DOE officials estimate that this technology will result in up to 28 percent energy savings for cooling, 31 percent heating energy savings and 23 percent peak demand energy savings compared to low-e and tinted low-e windows.



Reluctant to disclose Sage's price structure, Myser cites surveys showing that 13 percent of architects would be willing to pay more than $25 a square foot for electrochromic glass, 65 percent would pay more than $15 and 91 percent would pay more than $10.

Durability is always an issue in developing technology. The glass in residential windows today is typically warranted for up to 10 years, and the expectation is that the glass units will perform well beyond that.

Observing that electronically tinted windows will need to meet these industry expectations, Sage officials claim electrochromics durability has been proven during five years of testing samples of its prototype windows at third-party facilities, in-house and at government laboratories. The prototypes have shown lifetimes of more than 100,000 switching cycles with no noticeable degradation: 10 cycles a day for 27 years, or two cycles a day for 137 years.

Stephen Selkowitz, head of the Building Technologies Department at the Lawrence Berkeley lab, notes that the facility has been working 25 years on energy-efficient glazing. He predicts that more national attention will be focused on high energy costs. Since utility economists look at pricing power on a highly variable basis, Selkowitz says, "façade control would be more important." Among the potential benefits he sees in "smart glass" technology is not having to install shading systems.

"We're completely convinced of the benefits of smart technology; convinced some type of these windows are the way to go." he says, but, "Sage must demonstrate real effects. Manufacturers don't have credibility, they have an axe to grind. So our purpose is to be an objective third party."

Ren Anderson, residential project manager of the National Renewal Energy Laboratory at Lakewood, CO, calls the Sage experiment "exciting."

"There's broad interest in electrochromics from the window industry," Anderson says. "We're starting to see switchable energy with large-scale manufacturing capacity. Before it was just foot-by-foot. Now we're starting to see full-size windows."

Anderson names one "big issue" with Sage's technology: reducing "technical support barriers. The next question is really up to the marketplace, [to get] capital investment to bring costs down. This is out of our control. We hope it takes the market by storm but we'll see what happens. The price trends of other technologies' costs have fallen with time, [but] how far and how fast costs go down depends on the demand for product. It has to be a commodity before it gets a large share of the market."

Joe Wiehagen, project engineer at the National Association of Home Builders, says he sees "potential for some very good cost trade-offs" with Sage technology.

"We wouldn't be going there if we didn't think we can get there," he says. "The Sage product can work, but we need some more product development and evolution to define how much. There are lots of huge questions as to what would drive consumers; the convenience factor could drive it more than we know right now."

Advice From the Field

Wausau Window and Wall Systems of Wausau, WI, a supplier of aluminum windows and window-wall systems, provided specimens for test beds and has installed various manufacturers' electrochromic glass. Steve Fronek, Wausau's vice president for research and development, says there's certainly a need to build models to recognize operating and installation costs to justify the use of smart window technology.

"The pace of commercialization depends on market forces which will drive prices down," Fronek says. "It's an extremely promising technology [but it] requires much closer integration between all facets of the job than conventional windows. It will need a new design discipline; all members of the design and construction team must work together much more than in conventional glazing."

More confident is Richard Wind, general manager of Four Seasons Solar Products' commercial division, who had been working with Sage to install the world's first commercial electrochromics skylight. His firm, located in Holbrook, NY, is one of the country's largest sunroof manufacturers, and sees restaurants and offices as among those customers eager to change lighting with the push of a button.

"We're confident Sage will get costs down to be commercially successful," he says. With tests continuing at the Westchester County, NY, installation, he says, "there is a potential market for this. Otherwise, we wouldn't be spending our time."

Brian Binash, president of Houston's Emerald Homes, has built two identical homes as a residential field evaluation. He installed Sage glass in one and conventional glass in the other, and will measure the energy usage differences. Here, too, tests are continuing and no results are currently available.

Binash says he was "eager to get into cutting-edge technology in building energy-efficient homes. We think the technology has potential [but] we're not privy to [Sage's] cost information. "So far, so good," says Craig Dudley, Emerald's operations director. "It will be interesting to see how it will turn out."

Unmet Promise of Yet Another Coating

Reporting in the October issue of the Journal of Materials Chemistry, University College London researchers reveal the development of an intelligent window coating that, when applied to the glass of buildings or cars, reflects the sun's heat.

While conventional tints and coatings block heat and light, this coating allows visible wave lengths of light through, but reflects infrared light when the temperature rises over 29 degrees Celsius or 84 degrees Fahrenheit, the researchers claim in an August press release. Wave lengths of light in this region of the spectrum cause heating, so, blocking infrared reduces unwanted heat from the sun, the researchers write.

Made from a derivative of vanadium dioxide, the coating's ability to switch between absorbing and reflecting light means occupants benefit from the sun's heat in cooler conditions, but when temperatures soar, room heating is reduced by up to 50 percent.

Professor Ivan Parkin of UCL's Department of Chemistry and senior author of the paper, writes, "Technological innovations such as intelligent window coatings really open the door to more creative design. The current trend toward using glass extensively in buildings poses a dilemma for architects. Do they tint the glass, reducing the benefit of natural light, or face hefty air conditioning bills?

"While the heat-reflective properties of vanadium dioxide are well recognized, the stumbling block has been the switching temperature. It's not much good if the material starts to reflect infrared light at 70 degrees Celsius or 158 degrees Fahrenheit. We've shown it's possible to reduce the switching temperature to just above room temperature and manufacture it in a commercially viable way," Parkin writes.

Vanadium dioxide's properties are based on its ability to alternate between acting as a metal and semiconductor. The switch between reflecting or absorbing heat is accompanied by a small change in the structure of the material, where the arrangement of electrons changes. Vanadium-vanadium bonds are stable below the transition temperature that "locks" the electrons and prevent conduction. These vana-

Lisa Gonzalez, president and chief executive officer of Design Alternatives in Santa Clara, CA, likes the technology, but is skeptical about Sage's cost claims. She has noted that switchable glass can cost hundreds of dollars per square foot. She has tried to use SageGlass, she says, but finds it extremely expensive and hard to sell to potential customers. "If it were twice the regular cost, that might be price point. It's ideal to be able to push a button and avoid motorized screens."

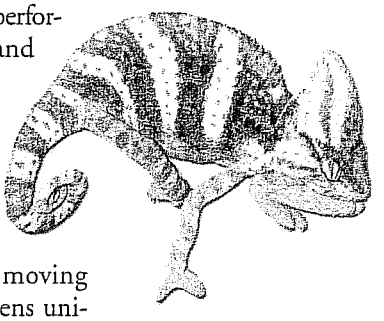
Suspended Particle Devices

Gonzalez' views agree with those of Sage technology rival Mike LaPointe, director of sales and marketing of Research Frontiers Inc. of Woodbury, NY, a developer of suspended particle device windows for more than 20 years. He terms Sage's two- to three-year payback estimate "wildly optimistic."

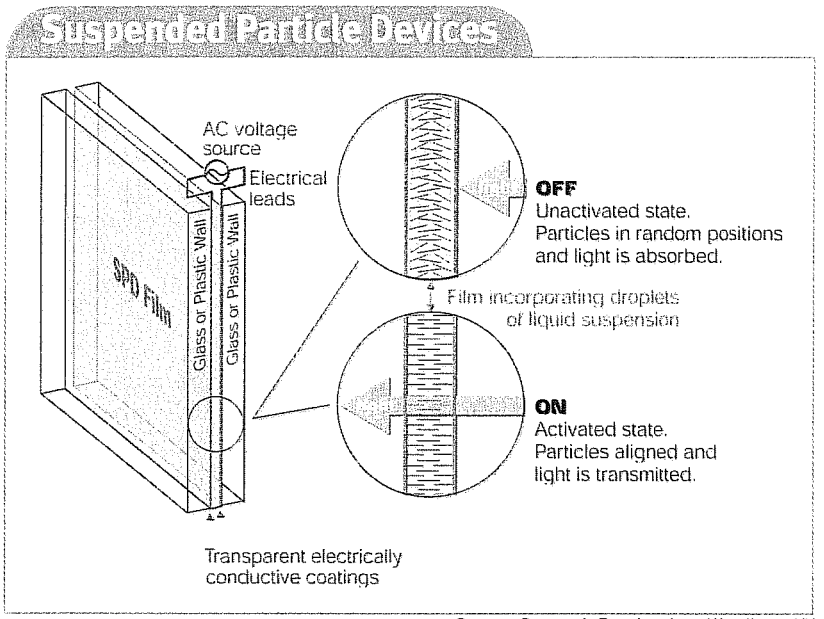
LaPointe says electrochromics' technology "works really well" in small installations such as rearview mirrors, but voices skepticism about whether it can ever get large-scale prices on a par with current low e-prices.

"Sage's panel test results look decent," he says, but "the problem is to get to the cost point, and that's almost impossible."

Suspended particle device windows cost about three times more than standard glass windows; a 40-inch-square window costs $3,000 to $3,500. SPDs use small light-absorbing microscopic particles, or light valves. Its developers claim these advantages over electrochromics: faster response time, darker "off" states, lower estimated costs, more reliable performance over a wider temperature range and lower current drain (see drawing below).



While suspended-particle glazing darkens in less than a second, an electrochromic mirror takes about six seconds to darken and up to 10 seconds to clear. Larger electrochromic panes would be even slower, and tend to darken at the edges before moving inward. A suspended particle device darkens uniformly. Unlike electrochromic glass, which works by containing a material that darkens when connected



Source: Research Frontiers Inc., Woodbury, NY

dium-vanadium bonds break above the transition temperature and the electrons are free to conduct electricity, making the material metallic.

Previous attempts to lower the switching temperature have incorporated low levels of elements such as tungsten, molybdenum, niobium and fluorine. These lower the transition temperature by supplying electrons into the material, which makes the metallic structure more stable.

By varying the levels of tungsten, the researchers were able to show that the optimum concentration was 1.9 percent. To make the coating cheaper to manufacture, a method of laying down the coating during glass manufacture was necessary.

Troy Manning, lead author of the study, now based at the University of Liverpool, explains: "For the glass manufacturing industry, one of the most important coating methods is atmospheric pressure chemical vapor deposition, because it allows the film to be deposited during the float-glass manufacturing process and is performed at atmospheric pressure, so no high-cost vacuum systems are required.

The research was funded by the Engineering and Physical Sciences Research Council.

Professor Parkin adds: "The next step in getting the coating to market is to investigate how durable it is. Ideally, because it's laid down at the point of manufacture, you want it to last for the lifetime of the window, but looking round you see many windows that date from the Victorian era, so we need the coating to last for over 100 years.

"Another consideration is the color of the coating," Parkin says. "At present it's yellow or green, which really isn't attractive for windows. So we're now looking into color suppression."

Mitch Edwards, manager of applications engineering at Guardian Industries Corp., in Carleton, MI, says that a Guardian scientist has done some work using vanadium as a component of a thermochromic film and found that while there were some slight positive thermal effects, the vanadium caused about a 10 percent drop in visible transmission. According to the Guardian scientist, the major drawback to the use of vanadium was a deep yellow transmitted color, Edwards says.

Sources

SageGlass: Mike Myser, vice president for sales and marketing, Sage Electrochromics Inc., 2150 Airport Drive, Faribault, MN 55021, 507/333-0078, info@sage-ec.com, www.sage-ec.com/pages/intro.html

Research Frontiers Inc.: Mike LaPointe, director of sales and marketing, 240 Crossways Park Drive, Woodbury, NY 11797, 888/SPD-or 516/364-1902, info@SmartGlass.com, www.refr-spd.com/index.html

Pulp Studio Inc.: Bernard Lax, president, 3211 La Cienega Blvd., Los Angles, CA 90016, 310/815-4999, sales@pulpstudio.com, www.pulpstudio.com

to a current of neutrally charged ions, a suspended particle device draws no current when tinted.

Research Frontiers, based in Woodbury, NY, granted four new licenses—bringing its total to 33—last spring: to Pilkington, to produce lamination and other services; to SmartGlass Ireland Ltd. of Dublin, to make and sell architectural window products; to Prelco, to make and sell architectural, residential and commercial windows, skylights and bus and train windows and sunroofs in Canada, Mexico and the United States, and to DuPont of Wilmington, DE, to sell architectural and auto window products worldwide.

Robert Saxe, chairman of Research Froniers, said at the company's annual meeting in June, "Unless and until one or more large orders are received by our licensees," it's unlikely that the company he founded in 1965 would be profitable. If one or more licensees get a thousand unit orders, he said, "this will be a clear signal that industry sees real merit in our SPD products."

Liquid-Crystal Technology

Another electronically switchable option uses liquid-crystal technology. A liquid-crystal sheet is bonded between two layers of glass. Once switched on, the voltage rearranges liquid-crystal molecules to let parallel light pass through the glass. When switched off, the molecules disperse light.

Bernard Lax, president of Los Angeles' Pulp Studios, manufacturer the liquid-crystal interlayer, says that this energy-efficient technology is primarily used in privacy glass. Pulp Studios specializes in interior work for high-security areas, laboratories and Hollywood sets.

Lax says that liquid-crystal technology is "unique but not new. In fact, scientists have been experimenting with liquid crystals ever since they were discovered in 1888. A lot of people have gone in and out of the business; they learned that that this is very much a niche business."

Striving to widen the liquid-crystal niche is Polytronix Inc.'s Jianlin Li, vice president of engineering at the Richardson, TX, facility. He uses a polymer-dispersed, liquid-crystal technology, patented by Ohio's Kent State University, where Li received his doctorate. A switch changes the view from cloudy white to optically clear.

Polyvision glass is now used in interior settings such as conference rooms, prisons and intensive-care areas. Li says the company is developing plans to work with a foreign consortium on other uses.

Nobody doubts that the various competing smart-glass technologies can lower costs; the question is whether these expenses can offset the extra glazing costs.